INTERACTIONS BETWEEN FRUIT-EATING BIRDS AND BIRD-DISPERSED PLANTS IN THE TROPICAL DRY EVERGREEN FOREST OF POINT CALIMERE, SOUTH INDIA

P. BALASUBRAMANIAN[1]

(With three text-figures)

This paper examines interactions between 64 fleshy-fruited plants and 20 fruit-eating birds in a tropical dry evergreen forest at Point Calimere Wildlife Sanctuary, India. Seasonal patterns of frugivore availability, fruiting phenology, fruit colour, fruit size and gape width of frugivorous birds were studied and compared. The timing of fruiting and frugivore abundance were significantly correlated. There was a peak in the number of plants in ripe fruits during post-monsoon when there was a peak in the frugivorous bird population. Fruiting decreased during summer and pre-monsoon and the frugivorous bird abundance was low in this period. Species such as *Walsura trifolia, Azadirachta indica, Lannea coromandelica, Crateva adansonii* that fruited during summer were found to be keystone food resources for fruit-eating birds. Most bird-dispersed fruits appear red or black (to human eyes). Yellow, blue, white, green and orange are the other bird-fruit colours, but are uncommon. The colour spectra of bird-dispersed fruits at Point Calimere correlated with other regions of the tropics. The gape width of birds and the number of fruit species eaten by frugivorous birds were not correlated. Birds ate fruits irrespective of their sizes. For those plants which possess fruits with smaller seeds, birds are suitable dispersers. In the case of large-seeded fruits, birds ate only the pulp and seeds were dropped. For these plant species, mammals (e.g. *Cynopterus sphinx* and *Canis aureus*) are the suitable dispersers.

INTRODUCTION

The study of relationships between bird-dispersed plants and fruit-eating birds in tropical region has received considerable attention (Ali 1931, Howe and Estabrook 1977, Frost 1980, Beehler 1983, Wheelwright *et al.* 1984, Gautier-Hion *et al.* 1985, Lambert 1989, Dowsett-Lemaire 1988, Green 1993). While certain studies were focused on the interactions between the timing of fruiting of bird-dispersed plants and the abundance of fruit-eating birds (e.g. Smythe 1970, Wheelwright 1985a, Leighton and Leighton 1983 and Levey 1988), other studies were focused on the fruit colour spectra of fleshy-fruited plants consumed by birds (e.g. Turcek 1963, Janson 1983, Willson and Thompson 1982, and Wheelwright and Janson 1985) and the relationship between the fruit size and gape width of fruit-eating birds (e.g. Pratt and Stiles 1985, Wheelwright 1985b, Willson *et al.* 1989).

The relationship between the timing of fruiting of bird-dispersed plants and fruit-eating bird abundance is basic to understanding the tropical bird-fruit dispersal syndromes. Temporal variation in tropical fruit-eating bird abundance is usually ascribed to changes in fruit abundance (Skutch 1967, Morton 1973, 1977; Karr *et al.* 1982).

As fruit production fluctuates in many tropical forests, certain species fruiting during periods of fruit scarcity might assume importance as " Keystone resources" (Terborgh 1986). Information on animal responses to resource availability and identifying certain species which play a dominant role in mutualistic interactions in the community are important in the conservation and management of natural habitats.

In bird-dispersed plants, fruit colour is one of the many factors determining fruit choice by birds in the wild (Wheelwright and Janson 1985). Ridley (1936) noted that fruit colours are a form of long distance advertisement to fruit foragers. He observed that red and\or black are the most common colours of bird-dispersed fruits. Subsequent surveys by various authors have supported his generalization for particular floras.

[1]Bombay Natural History Society, Hornbill House, Dr. Sálim Ali Chowk, S.B.Singh Road, Bombay-400 023.
Present address: Sálim Ali Centre for Ornithology and Natural History, Kalampalayam-PO, Coimbatore-641 010.

In fleshy-fruited plants, fruit size helps and constrains seed dispersal by animals. In tropical communities, it has been observed that small fruits attract a wider array of dispersal agents than larger ones. Plant species with small fruits are often visited by more species of dispersal agents (Snow 1971, Martin 1985, Howe and Westley 1988 and Dowsett-Lemaire 1988).

With this background, a study on the interrelationships between fleshy-fruited plants and their vertebrate consumers was conducted from May 1986 to December 1988 in the dry evergreen forest in Point Calimere, South India from where similar studies have not been carried out so far. The objectives of the study were: 1. to find out the relationship between the timing of fruiting of bird-dispersed plants and fruit-eating bird abundance, 2. colour spectra of fleshy fruits eaten by birds and 3. relationship between fruit size and gape width size of frugivorous birds.

Study Area and Methods

The study area, Point Calimere Wildlife Sanctuary (10°18' N, 79° 51' E) is situated at a low promontory on the Coromandel Coast in the Tamil Nadu state of India. The Sanctuary spreads out in an area of 2401.38 hectares. The Jaffna peninsula of Sri Lanka is about 50 km away across the Palk Strait. The elevation of the area is 4 metres above mean sea level at the highest point of the sanctuary.

The average rainfall of Point Calimere ranges from 1000-1500 mm (Meher-Homji 1984). The temperature ranges from 21.5°C (absolute minimum) during the least warm month, January to 35°C (absolute maximum) during the warmer months, April, May and June. The calendar year of this tropical region of southern India is divisible into the following four seasons based on rainfall. 1. Post-monsoon - January, February, March. 2. Summer-April, May, June. 3. Pre-monsoon-July, August, September. 4. Monsoon-October, November, December. The flora and the vegetation of the Sanctuary has been studied by Sebastine and Ellis (1967), and Blasco and Legris (1973). Balasubramanian (in press) gives a detailed account of the flora of this region. Champion and Seth (1968) classified the vegetation of this sanctuary under "Tropical dry evergreen forest" type. Wooded portion of the sanctuary is only 50% of the area; the rest is covered by shallow swamp and open grazing lands. About 140 species of passerine birds and 18 mammal species have been reported from Point Calimere (Rajan *et al.* in press).

The Plants: Phenological records were noted for tagged individuals along a four kilometre transect in the study area. Ten individuals of each species were selected. Phenological data were collected for 64 plant species that include 27 trees, 23 shrubs and 14 climbers. A total of 555 individuals were marked for the study. The phenological data on fruiting were collected once a fortnight from January 1987 to December 1988. The plants were observed through a pair of binoculars and the abundance of fruiting was noted. Three categories, namely 'none', 'few' and 'many' were employed to indicate abundance of ripe fruits. The details of methods followed are given elsewhere (Balasubramanian and Bole 1993b). Ten ripe fruits from five individuals of each of the bird-dispersed plant species were collected. The colour of the ripe fruits against their natural background was noted. The fruit colours were assigned into one of eight broad colour categories commonly employed by other researchers (Turcek 1963, Willson and Thompson 1982, Wheelwright and Janson 1985), namely black, blue, brown, red, green, yellow, orange and white. Fresh fruits were weighed and mean mass of each species was calculated. Fruit diameter was measured with Vernier calipers. The number of seeds in each fruit was counted. The length of each seed was measured.

The Birds: The abundance of the avian frugivores was estimated by a census from January 1987 to December 1988. Once in a fortnight a census walk was made along a four kilometre transect, where the plants for phenology studies had been marked. Birds seen and heard 50 metres on either side of the transect were recorded (Emlen 1971). The gape width (the distance between the commissural points) was measured with Vernier

calipers from the specimens of Bombay Natural History Society's collection. Avian nomenclature follows Ali and Ripley (1983).

Fruit-eating birds were identified by extended watches on fruit-bearing plants. The methods followed for recording bird visitation to fruiting plants are after Howe and Steven 1979, Frost 1980, Cruz 1981, Kantak 1981, Beehler 1983. Observations were made between 0600 and 0900 hr in the morning, usually for a continuous duration of three hours. The fruit utilisation by various birds was documented by identifying birds making feeding visits on fruiting plants. The number of visits made by each bird species was recorded for every five minutes during the three hour observation.

Results

Species Composition of Fleshy-fruited Plants: Out of 317 species of flowering plants in Point Calimere, 88 species have fleshy-fruits. Among these, 64 species that were eaten by birds were selected for the study. The remaining 24 species were not included in the study because (i) 10 plants were dispersed only by mammals; (ii) seven species were dispersed by water and (iii) the remaining seven species, though dispersed by birds occur either rarely in the study area or were annual climbers. The 64 species are in 53 genera belonging to 34 families. Families represented by most native genera with fleshy-fruits eaten by birds are Rubiaceae (4), Euphorbiaceae (4) and Cordiaceae (3).

Fruiting Phenology of Bird-dispersed plants: Fruiting at Point Calimere is seasonal; with a peak in winter (post-monsoon) and a trough in summer. Number of species with ripe fruits was lowest during June (summer) in both the years-1987, 1988 (Table 1). The number of species with fruits started to increase from October (monsoon) in the first year and in September (late pre-monsoon) in the second year. The peak in fruiting was attained during February (post-monsoon) in the first year (1987), during March (post-monsoon) in the second year (1988). There was no significant difference in the number of species in fruit between 1987 and 1988 (Wilcoxon's signed rank test, $p > 0.10$).

Salvadora persica produced sterile fruits, without seeds during February, March and April. During May, September and October it produced fertile fruits with seeds. The sterile fruit was a thin-skinned berry measuring 5 mm diameter. The fertile fruit measured 6.2 mm diameter with a seed of 3.5 mm diameter. Most of the individuals had red fruits, while a few had white fruits. A detailed account of the fruiting phenology of fleshy-fruited plants in Point Calimere is described elsewhere (Balasubramanian and Bole 1993b).

The Fruits: Table 2 summarizes the various classes of bird-fruits in Point Calimere. Red (25) and Black (17) are the principal colours, which constituted 65.6% of the total bird-fruit species in Point Calimere. Yellow, blue, white, green and orange are other colours among bird-fruits. Fruit size ranged from 3.9 mm to 69 mm. The majority of bird-dispersed fruits had a mean diameter of less than 10 mm (42 out of 64). A total of 42 fruit species had 1-2 seeds per fruit, out of which 35 species (55%) had only a single seed. A total of 55 fruit species had seeds measuring less than 10 mm length. Remaining nine species measured more than 10 mm in length.

The Birds: A total of 20 bird species of 14 genera from 10 families were observed to eat fruits at Point Calimere (Table 3). None of the families were represented by more than two genera. Families represented by more than two species were Sturnidae (4), Corvidae (3) and Columbidae (3). Based on the census data, the status of frugivorous birds were put into three classes, namely i. Residents (R); (birds that are seen throughout the year), ii. Seasonal migrants (SM); birds that are seen most part of the year and are absent for a short period (2-4 months) and iii. Migrants (M); birds that are seen for a short period, especially during winter.

The major avian seed dispersers are two bulbuls (*Pycnonotus luteolus, P. cafer*), three mynas (*Sturnus malabaricus, S. pagodarum, Acridotheres tristis*), Rosy pastor (*Sturnus roseus*), Golden oriole (*Oriolus oriolus*), Koel (*Eudynamys scolopacea*),

TABLE 1
FRUITING PHENOLOGY OF BIRD-DISPERSED PLANTS IN POINT CALIMERE

	Month												Year
	J	F	M	A	M	J	J	A	S	O	N	D	
Total species in fruit	27	30	28	23	17	12	13	15	18	24	26	24	1987
N=64	31	29	32	16	15	13	17	14	26	20	26	29	1988

two crows (*Corvus macrorhynchos, C. splendens*), Indian tree pie (*Dendrocitta vagabunda*), Jungle babbler (*Turdoides striatus*) and Tickell's flowerpecker (*Dicaeum erythrorhynchos*). Two doves *Streptopelia chinensis, S. decaocto*) and Rose-ringed parakeet (*Psittacula krameri*) were seed predators. *P. krameri* visited the fruiting trees mainly for eating the seeds. The fruits of Sapotaceae (e.g., *Manilkara hexandra, Mimusops elengi* and *Madhuca longifolia*) were largely attacked by this bird. *S. chinensis* and *S. decaocto* visit the fruiting trees mainly to eat the fruits, but while doing so they damage the seeds, and are hence included in this class. Though pigeons and doves are generally considered as seed predators (Ridley 1936), *Treron bicincta* was found to disperse seeds of a few plant species. The analysis of faeces collected from roosting sites showed a large number of uninjured seeds of *Manilkara hexandra* and *Zizyphus oenoplia.* Two sunbirds (*Nectarinia zeylonica* and *N. asiatica*) visited the plants such as *Lepisanthes tetraphylla* and *Salvadora persica,* bearing juicy fruits, to sip the

TABLE 2
FREQUENCY DISTRIBUTION OF 64 FRUIT SPECIES BASED ON DIFFERENT PARAMETERS

Fruit colour n=64	Black	Blue	Green	Orange	Red	White	Yellow
	17	5	2	2	25	4	9

Fruit diameter n=64	<10	10-20	>20
	42	14	8

Number of seeds n=64	1-2	3-15	>15
	42	12	10

Seed length (mm) n=64	<5	5-10	>10
	24	31	9

TABLE 3
AVIAN FRUGIVORES AND THEIR GAPE SIZE OBSERVED AT POINT CALIMERE

Family/Species	Common name	Code	Status	Gape Width (mm)	
				Mean	Range
COLUMBIDAE					
Treron bicincta	Orangebreasted Green Pigeon	(OP)	SM	10.3	9.7 - 11.0
Streptopelia decaocto	Indian Ring Dove	(RD)	R	7.9	7.8 - 8.0
Streptopelia chinensis	Spotted Dove	(SD)	R	8.6	7.1 - 10.0
PSITTACIDAE					
Psittacula krameri	Roseringed Parakeet	(RR)	R	14.6	13.7 - 15.3
CUCULIDAE					
Eudynamys scolopacea	Koel	(KL)	SM	17.5	15.5 - 19.7
ORIOLIDAE					
Oriolus oriolus	Golden Oriole	(GO)	SM	11.2	10.8 - 11.6
STURNIDAE					
Sturnus malabaricus	Greyheaded Myna	(GM)	SM	9.0	8.8 - 9.6
Sturnus pagodarum	Brahminy Myna	(BM)	SM	9.2	8.0 - 11.2
Sturnus roseus	Rosy Pastor	(RP)	M	9.6	9.2 - 10.2
Acridotheres tristis	Common Myna	(CM)	R	10.5	9.8 - 11.2
CORVIDAE					
Dendrocitta vagabunda	Indian Tree Pie	(TP)	R	14.5	13.7 - 14.9
Corvus splendens	House Crow	(HC)	R	19.0	16.8 - 19.9
Corvus macrorhynchos	Jungle Crow	(JC)	R	22.8	22.0 - 23.6
PYCNONOTIDAE					
Pycnonotus cafer	Redvented Bulbul	(RB)	R	9.5	8.9 - 10.0
Pycnonotus luteolus	Whitebrowed Bulbul	(WB)	R	11.4	11.2 - 12.0
MUSCICAPIDAE					
Turdoides striatus	Jungle Babbler	(JB)	R	11.6	10.5 - 12.6
Acrocephalus dumetorum	Blyth's Reed Warbler	(BW)	M	5.4	5.2 - 5.9
DICAEIDAE					
Dicaeum erythrorhynchos	Tickell's Flowerpecker	(TF)	R	5.0	4.6 - 5.5
NECTARINIDAE					
Nectarinia zeylonica	Purplerumped Sunbird	(PR)	R	4.7	4.5 - 4.8
Nectarinia asiatica	Purple Sunbird	(PS)	R	4.9	4.4 - 5.5

sweet juice. While doing so, the seeds are neither damaged nor ingested and hence the birds are called as fruit thieves. Blyth's reed warbler (*Acrocephalus dumetorum*) was neither a legitimate seed disperser nor a seed predator. It visited only one plant (*Salvadora persica*) to eat the seedless fruits which were ingested whole.

The various plant species whose fruits were eaten by birds at Point Calimere are given in Table 4. *Pycnonotus luteolus* visited the maximum number of plants (63) followed by *Pycnonotus cafer* (51), *Eudynamys scolopacea* (32) and *Acridotheres tristis* (27). Three plant species were visited by more than 10 bird species. The tree species with the largest number of bird species visit was *Salvadora persica* (15) followed by *Manilkara hexandra* (12) and *Ficus infectoria* (11). The percentages of visits made by various fruit eating birds to 22 fleshy-fruited plants are given in Table 5.

Seasonal Fluctuations of Frugivorous Birds: Fluctuation in the number of species as well as individuals of frugivorous birds was noticed during different seasons in both the years of study. The highest number of frugivorous bird species occurred during November (monsoon) in 1987 (17) and in December (monsoon), February and March (post-monsoon) in 1988 (19) (Fig. 1). There was a significant difference in the number of species that

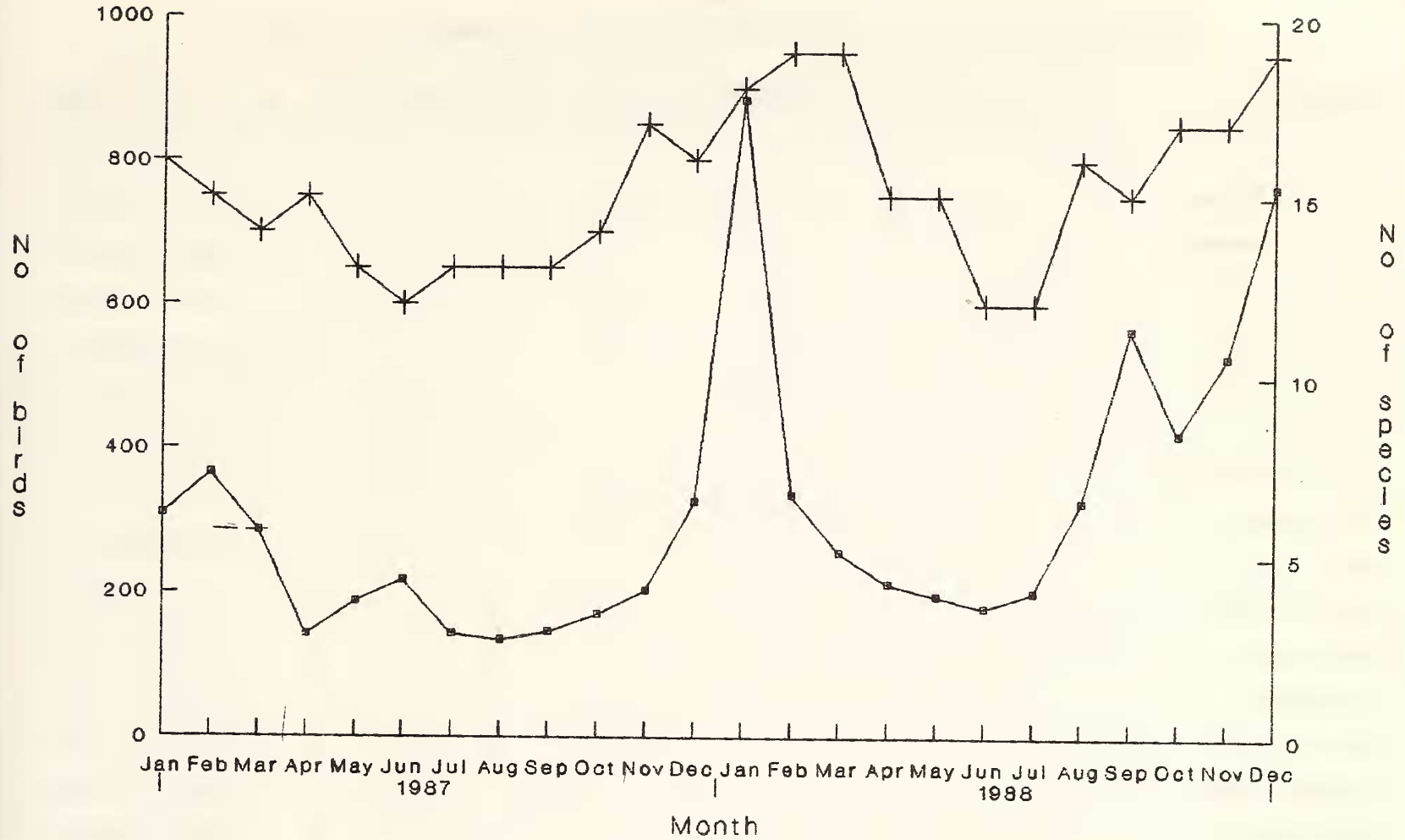

Fig. 1. Number of frugivorous bird species and individuals observed along census route.

occurred in 1987 and 1988 (Wilcoxon's signed rank test, $p < 0.05$). The number of frugivorous bird species was low during summer and pre-monsoon and the lowest number (12) occurred during June (summer) in 1987, and during June and July (summer and pre-monsoon) in 1988.

The lowest number of individuals of frugivorous birds (141) occurred during April (summer) in 1987, (180) in June (summer), in 1988 (Fig. 1). The number of individuals of frugivorous birds was generally low during summer and pre-monsoon in both the years. The highest number (364) of individuals of frugivorous birds occurred during February (post-monsoon) in 1987. In 1988, the highest number (764) was noticed in December (monsoon). In 1988 a small fruiting peak was noticed in September which was due to the influx of *Acridotheres tristis* from the neighbouring villages to *Syzygium cumini* trees, which were in mass fruiting. During summer and pre-monsoon (between June and August) resident birds were found in low numbers. During these seasons, species such as *Pycnonotus luteolus, P.cafer, Acridotheres tristis, Streptopelia chinensis* and *S. decaocto* made local migrations to the neighbouring villages in search of food.

Gape Width Size: The mean gape width of fruit-eating birds ranged from 4.7 mm to 22.8 mm. However, if sunbirds and Blyth's reed warbler which are non seed dispersers and Tickell's flowerpecker which is specialized in dispersing the seeds of mistletoes are excluded, the mean gape width diameter ranges from 7.9 to 22.8 mm.

Discussion

In Point Calimere, a significant correlation was noticed between the number of plant species in ripe

TABLE 4
FRUIT SPECIES EATEN BY VARIOUS BIRDS AT POINT CALIMERE SANCTUARY*

Plant species	OP	RD	SD	RR	GO	GM	BM	RP	CM	HC	JC	RB	WB	JB	TF	PR	PS	TOTAL
Pachygone ovata												d	d					2
Tinospora cordifolia							d	d	d	d	d	d	d					8
Capparis rotundifolia												d	d					2
Capparis zeylanica													d					1
Cretaeva adansonii													d					1
Flacourtia indica							d					d	d					4
Hugonia mystax											d	d	d					4
Glycosmis pentaphylla									d			d	d			t		4
Toddalia asiatica			p				d	d	d			d	d					7
Ochna obtusata													d					1
Azadirachta indica												d	d					2
Walsura trifolia	+											d	d					3
Olax scandens									d			d	d	d				5
Cansjera rheedii									d			d	d					4
Pleurostylia opposita										d		d	d					3
Salacia chinensis			+									d	d					3
Scutia myrtina												d	d					3
Zizyphus mauritiana													t					2
Zizyphus oenoplia						d	d		d			d	d					6
Cissus quadrangularis												d	d	d				4
Cissus vitiginea							d					d	d	d				4
Allophyllus serratus									d			d	d					3
Lepisanthes tetraphylla												t	+	+	t	t	t	6
Lannea coromandelica									d	d	d	d	d					6
Syzygium cumini	t								d			t	t					5
Memecylon umbellatum												d	d					2
Coccinia grandis		d	d	d		d	d		d			d	d	d				10
Trichosanthes cucumerina									d	d			d					4
Trichosanthes tricuspidata										d	d		d					5
Opuntia dillenii												d	d					2
Benkara malabarica												d	d					2
Canthium dicoccum									d			d	d	d				6
Canthium parviflorum									d		d	d	d					4
Ixora pavetta									d			d	d					4
Pavetta breviflora												d	d					3

* for bird species code see Table 3

TABLE 4 (*continued*)

Plant species	OP	RD	SD	RR	GO	GM	BM	RP	CM	HC	JC	RB	WB	JB	TF	PR	PS	TOTAL
Pavetta indica													d					1
Manilkara hexandra	d		p	p		d	d		d	d	d	t	t		t			12
Mimusops elengi				p									+					2
Diospyros ferrea												d	d					3
Jasminum angustifolium									d	d		d	d					4
Jasminum auriculatum									d				d					3
Azima tetracantha												d	d					2
Salvadora persica		+	+	p		+	+	+	d	d	d	d	d	d			+	15
Carissa spinarum												d	d					2
Carmona retusa												d	d	d				3
Cordia obliqua												d	d	d				3
Ehretia ovalifolia							d		d		d	d	d					6
Solanum trilobatum												d	d					3
Premna serratifolia									d			d	d					4
Cassytha filiformis													d		t			2
Dendrophthoe falcata															d			1
Viscum orientale													d		d			2
Viscum capitellatum													d		d			2
Breynia vitis-idaea												d	d					2
Drypetes sepiaria									d			d	d					4
Phyllanthus reticulatus												d	d					2
Securinega leucopyrus							d		d			d	d	d				6
Ficus benghalensis					d				d	d	d	d	d	d				9
Ficus microcarpa									d	d	d	d	d	d				8
Ficus religiosa					d				d	d	d	d	d					8
Ficus infectoria	d		d		d				d	d	d	d	d		d			11
Plecospermum spinosum	t								d			t	t					5
Asparagus racemosus												d	d					3
Phoenix pusilla												d	d					2
Total species eaten	5	2	6	4	3	4	10	3	27	12	12	51	63	12	7	2	2	

d = Seed disperser; p = Seed predator; t = Fruit thief; + = Unknown

For bird species names see Code in Table 3.

TABLE 5
PERCENTAGES OF VISITS MADE AND FRUITS CONSUMED BY THE FRUGIVOROUS BIRDS FROM VARIOUS BIRD-DISPERSED PLANTS

	Bird Species														
Plant Species	KL	CM	BM	GM	RP	TP	HC	JC	WB	RB	JB	OTH	Total	Visits *	Hours
Azadirachta indica									99.6	0.4			2	74	12
									(99)	(1)				(86)	
Cansjera rheedii	15	1							49	35			4	7	12
	(45)	(2)							(27)	(26)				(30)	
Canthium dicoccum	6	17				1			37	37	1		6	14	12
	(20)	(30)			(1)			(23)	(25)	(1)				(70)	
Cissus vitiginea			4						67	25	2		4	4	18
			(11)						(67)	(20)	(2)			(10)	
Cordia obliqua									89	10	1		3	19	12
									(87)	(12)	(1)			(49)	
Diospyros ferrea	9								85	6			3	3	12
	(23)								(76)	(1)				(12)	
Drypetes sepiaria	3	12							49	36			4	8	17
	(8)	(22)							(34)	(36)				(29)	
Ehretia ovalifolia	1	5	2					1	57	34			6	20	12
	(9)	(8)	(6)					(2)	(45)	(30)				(73)	
Ficus benghalensis	3	22				1	23	43	3.5	3.5	0.5	0.5	9	40	12
	(4)	(23)				(1)	(15)	(54)	(1)	(1)	(0.5)	(0.5)		(326)	
Ficus religiosa	2	31				1	6	12	27	18	3		8	31	17
	(9)	(37)				(3)	(6)	(8)	(18)	(17)	(2)			(140)	
Ficus infectoria	2	7				1	9	11	12	54	1	3	11	35	14
	(4)	(7)				(1)	(10)	(14)	(11)	(49)	(0.5)	(0.5)		(115)	
Glycosmis pentaphylla		5							83	9		3	3	6	15
		(30)							(59)	(11)				(13)	
Ixora pavetta	6	1							62	31			4	10	18
	(30)	(3)							(49)	(18)				(49)	
Manilkara hexandra	6	16	7	4			12	2.5	28	2		22.5	12	10	33
	(19)	(31)	(6)	(9)			(28)	(5)	(0)	(0)		(2)		(40)	
Olax scandens	8.5	18							58.5	8	7		5	9	15
	(23)	(33)							(32)	(4)	(8)			(49)	
Phyllanthus reticulatus	17								26	57			3	6	12
	(34)								(20)	(46)				(25)	
Salvadora persica	1	24					11.5	12	23	19.5		9	9	16	21
	(1)	(38)					(16.5)	(21)	(11)	(12)				(127)	
Securinega leucopyrus	0.5	22	51.5						11	13	2		6	18.5	12
	(1)	(14)	(54)						(3.5)	(6)	(1.5)			(217)	
Solanum trilobatum		4							39	57			3	6	12
		(31)							(14.5)	(54.5)				(20)	
Tinospora cordifolia	10.5	13.5	1.5		2		5	1.5	41	25			8	7	20
	(20)	(21)	(1)		(3)		(12.5)	(2)	(26)	(14.5)				(34)	
Toddalia asiatica	4	2	11		3				41	38		1	7	10	15
	(8.5)	(4.5)	(12)		(7)				(36)	(30)		(2)		(41)	
Zizyphus oenoplia	0.5	21	28.5	23					14	13			6	26	15
	(0.5)	(27.5)	(32)	(31)					(5)	(4)				(289)	

TOT = Number of species recorded during observation period. For each species the given data represents the percentage of visits made by species,and (below, in parenthesis) the percentage of fruits removed by that species. * = Mean number of visits/hr and (below, in parenthesis) mean number of fruits consumed/hr.

For bird species names see Code in Table 3.

fruits and the number of fruit-eating bird species as well as individuals (Spearman rank correlation, $p < 0.05$). The migratory season (October-March) of birds corresponds with the availability of more fruit-bearing plant species. As the number of plant species that fruited during summer and pre-monsoon was very low, resident fruit-eating birds, namely *Pycnonotus luteolus, P.cafer, Streptopelia chinensis,* and *S. decaocto* showed local migration. These birds emigrated to neighbouring villages , six kilometre away from the sanctuary (Alagar Rajan, pers. comm.). Hence, bird-dispersed tree species such as *Walsura trifolia, Azadirachta indica, Lannea coromandelica, Crateva adansonii* and *Cordia obliqua,* whose fruiting was confined to the lean period and supports a large population of resident fruit-eating birds, become the keystone food resources in the community. All studies of tropical fruiting phenologies report seasonality, ranging from the extreme in forests with a distinct wet and dry season to minor in forests with heavy rainfall throughout the year (Howe and Smallwood 1982). In the forests with distinct wet and dry seasons, food may be more limiting in some seasons than in others. Consequently, trees which fruit during the lean season will play a greater role in maintaining entire communities of fruit-eating animals (Howe 1984).

A fine coordination between the frugivore abundance and fruit availability was noticed in the Bornean rain forest. Emigration of fruit-eating birds such as hornbills (*Rhyticeros*), pigeons (*Ducula, Ptilinopus*), the hill mynah (*Gracula*) and green broadbill (*Calyptomena*) during low fruit availability was noticed in the Bornean rain forest (Leighton and Leighton 1983). Foster (1982) described starvation of frugivores following climatically induced fruit crop failures on Barro Colorado Island, Panama, in 1970. Seasonal shift in fruit abundance was correlated with the fluctuating availability of fruit-eating birds at La Selva (Levey 1988).

Salvadora persica produced seedless fruits during February to April during which about 15 bird species visited it to eat the fruits. Flocks of *Sturnus roseus* visited the fruiting plants. Very large numbers of *S. roseus* were noticed only during these months. The birds fed voraciously on the fruits. The migrant bird, *Acrocephalus dumetorum,* which is chiefly insectivorous, was also found to feed on the fruits of *Salvadora.* The population of *A. dumetorum* was high during these months.

In South Africa, warblers *Sylvia*, bulbuls *Pycnonotus* spp., weavers *Ploceus* spp., sparrows *Passer* spp., Bluenaped Mousebirds *Colius macrourus*, and Yellow-Fronted Tinkers *Pogoniulus chrysoconus* visiting *Salvadora persica* trees to feed on the sterile fruits were reported by Fry *et al.* (1970). They found that *S. persica* fruits are lipid free and sugar-rich and readily assimilable by birds. From the retrapped birds, during that season, they recorded the weight variation in those bird species and concluded that migratory birds lay down fat before the return migration and also that the insectivorous birds could change their diet from the protein rich insects to sugar-rich pulpy fruits.

From the observations made at Point Calimere on the visitation of *Acrocephalus dumetorum,* an insectivorous bird, to *Salvadora persica* for feeding on the sterile fruits and the seasonal abundance and large scale visitation of *Sturnus roseus* to *Salvadora persica*, it can be presumed that these two bird species eat *Salvadora persica* fruits mainly to lay down their fat reserves, before starting on the return migration. The seedless fruiting by *Salvadora persica* during this season readily helps these two bird species in this purpose.

Fruit Colour Spectra of Bird-dispersed Plants: Published data for fruit colour spectra of the bird-dispersed plants of certain other geographic regions can be compared with those of Point Calimere. Wheelwright and Janson (1985) found no differences in fruit colour spectra in Costa Rica, Peru and Florida, where black-fruited species were the most common (34-41%). In European flora, red fruited species are more common (Turcek 1963). Bird-fruits from other regions were red (see Gautier-Hion *et al.* 1985 for Gabon; Knight and Siegfried 1983 for South Africa, and Beehler 1983 for New Guinea). In Point Calimere red followed by black

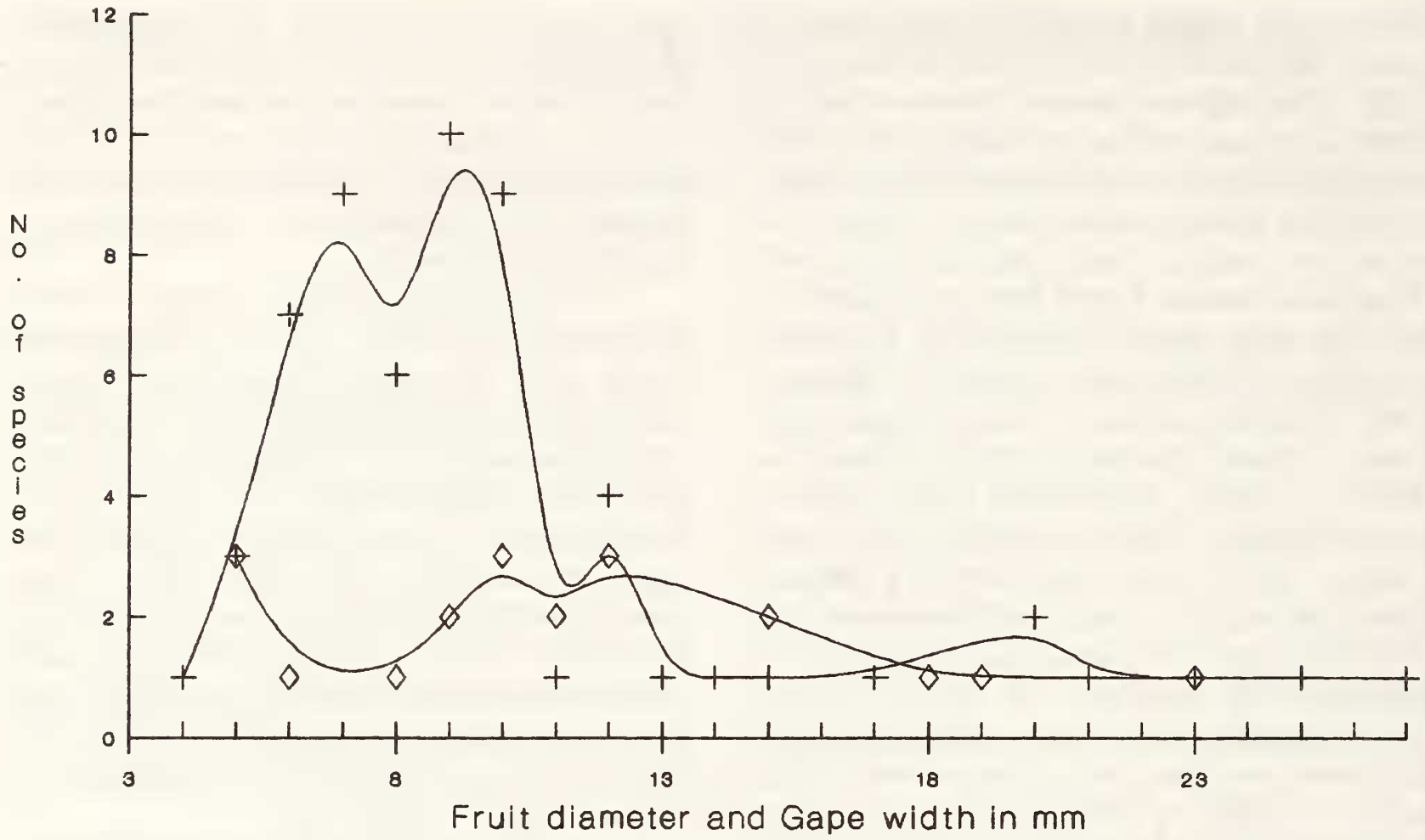

Fig. 2. Frequency distributions of mean diameter of fruits and gape width of frugivorous birds

are the principal colours among bird-fruits, which corresponds with the other regions.

At Point Calimere there was an association between small size and black and red colours of fruits. A total of 16 fruits out of 17 black and 14 out of 25 red had fruits measuring less than 10 mm diameter. Thus, the black and red fruits being smaller-sized, are easily consumed by birds, and contribute a significant share in the food plants of frugivorous birds of Point Calimere.

Fruit Size and Number of Seeds: The majority of bird-fruits in Point Calimere have a mean diameter of 4-20 mm. In the lower montane rain forests of Costa Rica, the majority of plant species (69.1%) had fruits with a diameter of 5-12 mm. About 48.9% of the species had single-seeded fruits. Only 23.8% of fruits had more than 10 seeds (Wheelwright 1985b). In Eastern North America, the size of the bird-fruits ranges from < 5 to 10 mm. In east-central Illinois, the mean diameter of many bird-fruit species is about 7-8 mm. The average number of seeds per fruit varies from 1-36 in 21 species, out of which 14 species average only one or two seeds per unit (Johnson *et al.* 1985). In Papua New Guinea, the fruit diameter of figs ranges from 6-28 mm, berries and drupes 6-20 mm (Beehler 1983). The Point Calimere figures correspond with those of the bird-dispersed fruit characters reported for the study areas such as New Guinea (Beehler 1983), Illinois (Johnson *et al.* 1985) and Costa Rica (Wheelwright 1985b).

Fruit Size and Gape Width: The fruit diameters of bird-dispersed plants at Point Calimere ranged from 3.9-69.0 mm. The gape width of the frugivorous bird species ranged from 4.7-22.8 mm. The distribution of gape width sizes of fruit-eating birds at Point Calimere did not match fruit diameters (Fig. 2).

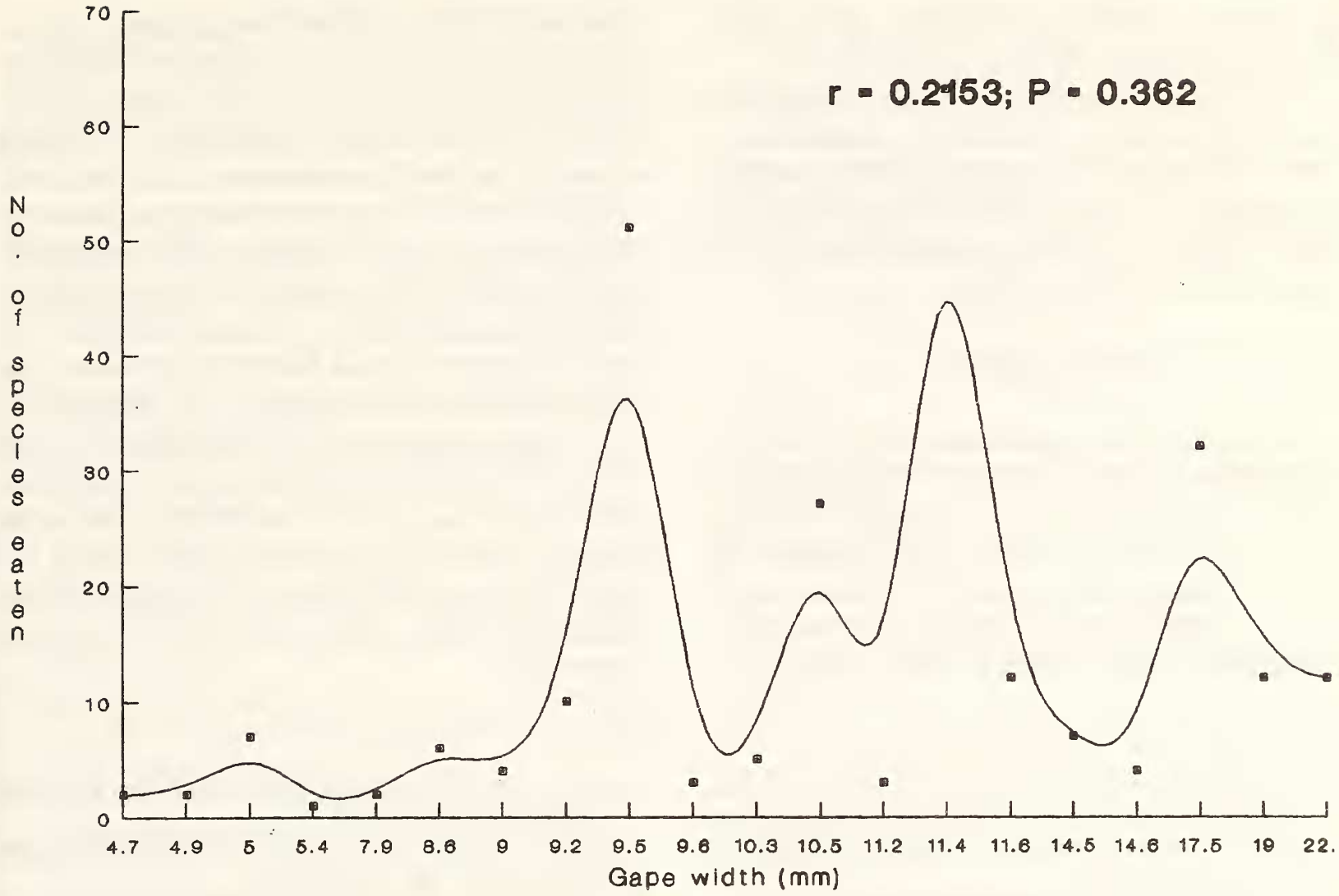

Fig. 3. Gape widths of birds *vs* number of fruit species eaten

Irrespective of their gape width, birds ate fruits of various sizes. In the case of larger fruits, birds with large gape width swallowed the whole fruit, whereas the birds with smaller gape width ate the pulp only. Seeds which could not be swallowed were dropped. Birds with relatively small or large gape width visited fewer plant species while birds of medium-sized gape width visited the largest number of plant species (Fig. 3). However, there was no significant correlation between gape width size and the number of fruit species eaten ($r = 0.2153$; $p = 0.362$).

According to Terborgh and Diamond (1970), small-fruited plant species attract more bird species than large-fruited ones. In Mexico, intermediate-sized fruits draw the largest number of bird species (Kantak 1979). Wheelwright (1985b) concludes that 1. small-fruited plant species draw significantly more species of birds than large-fruited ones, 2. large-gaped birds feed commonly on small fruits; and 3. a correlation exists between the gape width size and the number of lauraceous fruits eaten by those birds. The results of this study agree with the first two of these points of Wheelwright (1985b) and disagree with the third point, the reason being that Wheelwright's observations were on one guild (lauraceous) of plants and frugivorous birds and the present study is on plants in a whole community and fruit-eating birds.

In addition to birds, the Short-nosed Fruit bat (*Cynopterus sphinx*) Jackal (*Canis aureus*), small Indian civet (*Viverricula indica*) and the Bonnet Monkey (*Macaca radiata*) also dispersed the seeds of fleshy-fruited plants. Out of 64 bird-dispersed plants, 30 species were dispersed by *Cynopterus sphinx*, 20 by *V. indica* and 18 by *C. aureus*. Fruit species that were not eaten by birds (e.g., *Atalantia monophylla, Gmelina asiatica, Achras sapota* and

Madhuca longifolia) are dispersed by *C. sphinx* (Balasubramanian and Bole 1993a).

Even though nearly 50% of the fleshy-fruited species in Point Calimere are eaten by mammals, only 10% of the species are solely dispersed by mammals. For the remaining species, birds were the main dispersal agents. Therefore, most seed dissemination in this forest must be attributed to birds.

Acknowledgements

I record my deep gratitude to Prof. P. V. Bole, Ex-President, Bombay Natural History Society (BNHS) whose constant interest, attention, criticism, advice and encouragement have been invaluable. My sincere thanks are due to Mr. J. C. Daniel, former Director, BNHS for going through this manuscript. I am grateful to Prof. Henry F. Howe, University of Iowa who offered valuable suggestions for the collection of data, Dr. Rene Borges, Dr. P. Davidar, Dr. K.Thiyagaesan, Mr. S.A.Hussain and Dr. Y.N.Rao for their valuable suggestions in the analysis of data; Dr. Neil Armantrout of U.S. Fish and Wildlife Service who was of great help in procuring the literature; Dr. Ajith Kumar and two anonymous referees who have gone through the manuscript; Dr. V.S. Vijayan, Director, Sálim Ali Centre for Ornithology and Natural History for providing me the facilities while preparing this manuscript; Dr. N. Henry and other staff of Botanical Survey of India, Coimbatore for help in the identification of plants; the U.S. Fish and Wildlife Service for financial assistance and the officials of the Tamil Nadu Forest Department for permitting me to undertake this study at Point Calimere Sanctuary.

References

Ali, S. (1931): The role of sunbirds and flowerpeckers in the propagation and distribution of the tree-parasite *Loranthus longiflorus* Desr. in the Konkan (W. India). *J. Bombay nat. Hist. Soc. 35*: 144-149.

Ali, S. & S.D. Ripley (1983): Handbook of the Birds of India and Pakistan. Compact Edition. Oxford University Press, New Delhi.

Balasubramanian, P. (in press): Flora of Point Calimere *In*: S.A. Rajan, P. Balasubramanian, and V. Natarajan (Eds.), Biology of Point Calimere; A baseline study. Bombay Natural History Society, Bombay.

Balasubramanian, P. & P.V. Bole (1993a): Seed dispersal by mammals at Point Calimere Wildlife Sanctuary. *J. Bombay nat. Hist. Soc. 90(1)*: 33-44.

Balasubramanian, P. & P.V. Bole (1993b): Fruiting phenology and seasonality in the tropical dry evergreen forest in Point Calimere Wildlife Sanctuary. *J. Bombay nat. Hist.Soc. 90(2)*: 163-177.

Blasco, F. & P. Legris (1973): Dry Evergreen Forest of Point Calimere and Marakanam. *J. Bombay nat. Hist. Soc. 70*: 279-294.

Beehler, B. (1983): Frugivory and Polygamy in birds of paradise. *Auk 100*: 1-12.

Champion, H.G. & S.K. Seth (1968): A revised survey of the forest types of India. Government of India Publications, New Delhi.

Cruz, A. (1981): Bird activity and seed dispersal of a montane forest tree (*Dunalia arborescens*) in Jamaica. *Biotropica 13* (Supplement): 34-44.

Dowsett-Lemaire, F. (1988): Fruit choice and seed dissemination in the evergreen forests of upland Malawi. *Review of Ecology* (Terre et vie) *43*: 251- 285.

Emlen, J.T. (1971): Population densities of birds derived from transect counts. *Auk 88*: 323-342.

Foster,R.B. (1982): The seasonal rhythm of fruit fall on Barro Colorado Island. Pp. 151-172. *In*: E.G. Leigh Jr., A.S. Rand, D. Windsor, Eds. The ecology of a tropical forest; seasonal rhythms and long-term changes. Smithsonian Institution Press, Washington D.C.

Frost, P.G.H. (1980): Fruit-frugivore interactions in a South African coastal dune forest. Pp. 1179-1184 in Acta XVII Congressus inter-nationalis Ornithologici. R. Nohring (Ed.) Verlag Der Deutschen Ornighologen- Gesellschaft, Berlin.

Fry, C.H., J.S. Ash & I.J. Ferguson-Lees (1970): Spring weights of some palaearctic migrants at lake Chad. *Ibis 112*: 58-82.

Gautier-Hion, A., J.M. Duplantier, R. Quris, F. Feer, C. Sourd, J.P. Decoux, G. Dubost, L. Emmons, C. Erard, P. Hecketsweiler, A. Moungazi, C. Roussilhon & J.M. Thiollay (1985): Fruit characters as a basis of fruit choice and seed dispersal in a tropical forest vertebrate community. *Oecologia 65*: 324-337.

Green, R.J. (1993): Avian seed dispersal in and near subtropical rainforests. *Wildl. Res. 20*: 535-557.

Howe, H.F. (1984): Implications of seed dispersal by animals for tropical reserve management. *Biological Conservation 30*: 261-281.

Howe, H.F. & G.F. Estabrook (1977): On intraspecific competition for avian dispersers in tropical trees. *American Naturalist 111*: 817-832.

HOWE, H.F. & J. SMALLWOOD (1982): Ecology of seed dispersal. *Annual Review of Ecology and Systematics 13*: 201-228.

HOWE, H.F. & D.D. STEVEN (1979): Fruit production, migrant bird visitation, and seed dispersal of *Guarea glabra* in Panama. *Oecologia* (Berlin) *39*: 185-196.

HOWE, H.F. & L.C. WESTLEY (1988): Ecological relationships of plants and animals. Oxford University Press, Oxford.

JANSON, C.H. (1983): Adaptation of fruit morphology to dispersal agents in a neotropical forest. *Science 219*: 187- 189.

JOHNSON, R.A., M.F. WILLSON, J.N. THOMPSON & R.I. BERTIN (1985): Nutritional values of wild fruits and consumption by migrant frugivorous birds. *Ecology 66*: 819-827.

KANTAK, G.E. (1979): Observations on some fruit-eating birds in Mexico. *Auk 96*: 183-186.

KANTAK, G.E. (1981): Temporal feeding patterns of some tropical frugivores. *Condor 83*: 185-187.

KARR, J.R., D.W. SCHEMSKE & N. BORKAW (1982): Temporal variation in the undergrowth bird community of a tropical forest. Pp. 441-453. *In*: E.G. Leigh, Jr., A.S. Rand and D. Windsor (eds.) The ecology of a tropical forest; seasonal rhythms and longterm changes. Smithsonian Institution press, Washington D.C.

KNIGHT, R.S. & W.R. SIEGFRIED (1983): Interrelationships between type, size and colour of fruits and dispersal in South African trees. *Oecologia 56*: 405-412.

LAMBERT, F.R. (1989): Fig-eating by birds in a Malaysian lowland rain forest. *Journal of Tropical Ecology 5*: 401- 412.

LEIGHTON, M., & D.R. LEIGHTON (1983): Vertebrate responses to fruiting seasonality within a Bornean rain forest, Pp. 181-196. *In*: S.L. Sutton, T.C. Whitmore and A.C. Chadwick (Eds.) Tropical Rain Forest; Ecology and management. Blackwell Scientific Publishers, London.

LEVEY, D.J. (1988): Spatial and temporal variation in Costa Rican fruit and fruit-eating bird abundance. *Ecological Monographs 58(4)*: 251-269.

MARTIN, T.E. (1985): Resource selection by tropical frugivorous birds; integrating multiple interactions. *Oecologia 66*:563-573.

MEHER-HOMJI, V.M. (1984): A new classification of the phytogeographic zones of India. *Indian Journal of Botany 7*: 224-233.

MORTON, E.S. (1973): On the evolutionary advantages and disadvantages of fruit-eating in tropical birds. *American Naturalist 197*: 8-22.

MORTON, E.S. (1977): Intratropical migration in the yellow-green vireo and piratic flycatcher. *Auk 94*: 97-106.

PRATT, T.K. & E.W. STILES (1985): The influence of fruit size and structure on composition of frugivore assemblages in New Guinea. *Biotropica 17*: 314-321.

RAJAN, S.A., P. BALASUBRAMANIAN & V. NATARAJAN (In press): The Biology of Point Calimere-A Baseline Study. Bombay Natural History Society, Bombay.

RIDLEY, H.N. (1936): The dispersal of plants throughout the world. Reeve & Co., Ltd., Ashford.

SEBASTINE, K.M. & J.L. ELLIS (1967): A contribution to the Vascular flora of Vedharanyam and Talaignayar Reserve Forests, Tanjore District, Madras State. *Bulletin of the Botanical Survey of India 9*: 190-200.

SKUTCH, A.F. (1967): Life histories of central American highland birds. Nuttall Ornithological Club. No. 7. Cambridge, Mass.

SMYTHE, N. (1970): Relationships between fruiting seasons and seed dispersal methods in a neotropical forest. *American Naturalist 104*: 25-35.

SNOW, D.W. (1971): Evolutionary aspects of fruit-eating by birds. *Ibis 113*: 194-202.

TERBORGH, J.W. (1986): Keystone plant resources in the tropical forest. *In*: Soule, M.E.(ed.) Conservation Biology, The Science of scarcity and diversity. Sinauer Associates Inc. Massachussets. 584 pp.

TERBORGH, J.W. & J.M. DIAMOND (1970): Niche overlap in feeding assemblages of New Guinea birds. *Wilson Bulletin 82*: 29-52.

TURCEK, F.J. (1963): Colour preferences in fruit and seed eating birds. *Proc. XIII International Ornithological Congress* 285-292.

WHEELWRIGHT, N.T., W.A. HABER, K.G. MURRAY & C. GUINDON (1984): Tropical fruit-eating birds and their food plants: A study of a Costa Rican lower montane forest. *Biotropica 16*: 173-192.

WHEELWRIGHT, N.T. (1985b): Fruit size, gape width, and the diets of fruit-eating birds. *Ecology* 66: 808-818.

WHEELWRIGHT, N.T. (1985a): Competition for dispersers, and the timing of flowering and fruiting in a guild of tropical trees. *Oikos 44*: 465-477.

WHEELWRIGHT, N.T. & C.H. JANSON (1985): Colors of fruit displays of bird-dispersed plants in two tropical forests. *American Naturalist 126*: 777-799.

WILLSON, M.F. & J.N. THOMPSON (1982): Phenology and Ecology of color in bird-dispersed fruits, or why some fruits are red when they are "green". *Canadian Journal of Botany 60*: 701-713.

WILLSON, M.F., A.K. IRVINE. & N.G. WALSH (1989): Vertebrate dispersal syndromes in some Australian and New Zealand plant communities, with geographic comparisons. *Biotropica 21(2)*: 133-147.